



Experiments and Analysis

LARP Collaboration Meeting

Port-Jefferson September 16-18, 2003

Shlomo Caspi

BERKELEY LAB

9/18/2003

Superconducting Magnet Program

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Pre-stress and Training

We are just beginning to quantify the relation between transverse and axial stress during operation, and its impact on coil displacements.

Study sensitivity of pre-stress on coil displacements

- Transverse and axial
- Consider friction



Coil Experiments

- Spot heater tests
- Passive heaters
- Explore high stress limits (>150Mpa)
- Coil strain measurements

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Heat Load Studies

Compute heat load on the conductor and structure
 $(\text{Watts}/\text{Volume}) = f(x,y,z)$

Use ANSYS to calculate temperature rise, determine quench initiation and cooling effects



Pulsed Heater Experiments

Compare pulsed heater response with 3D calculations

- Propagation velocity
- Temperature rise
- Voltage rise
- Stress rise

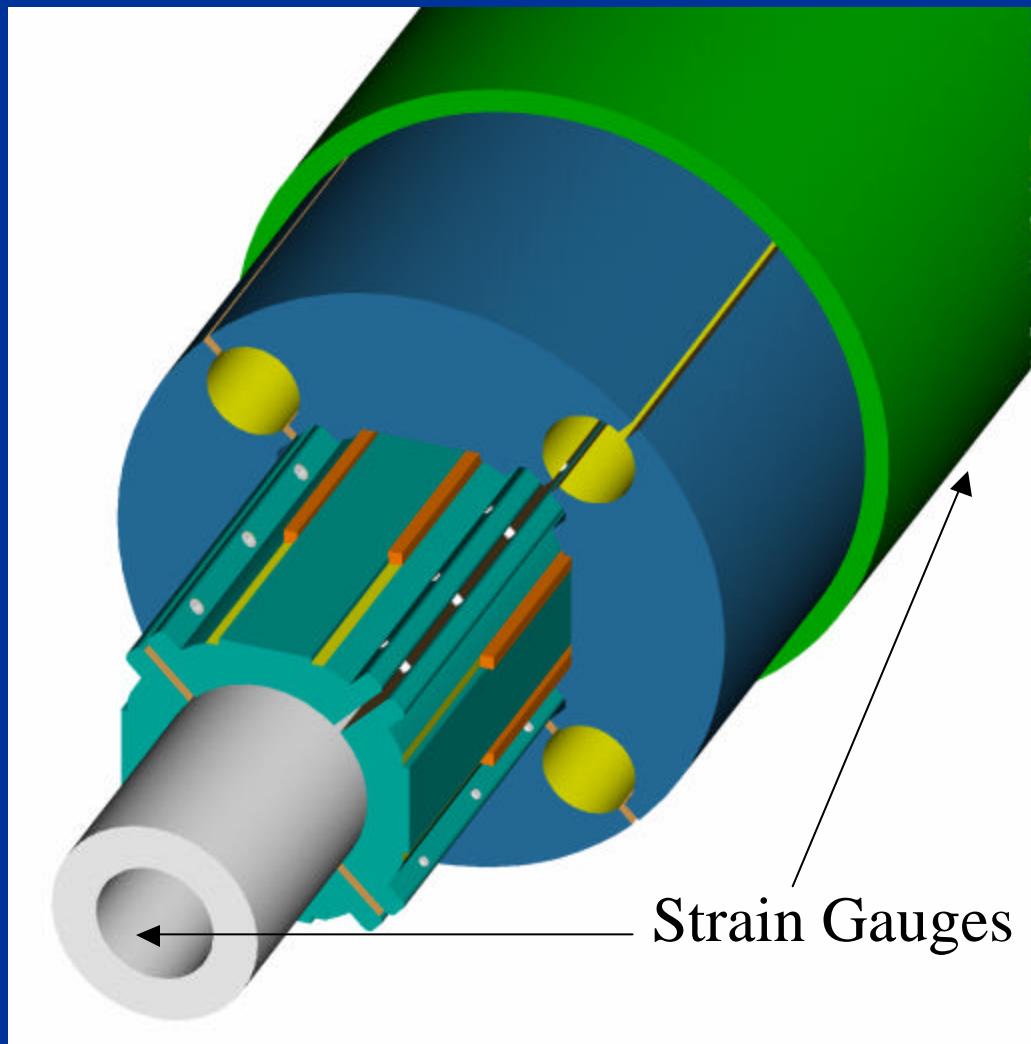
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Structure Test

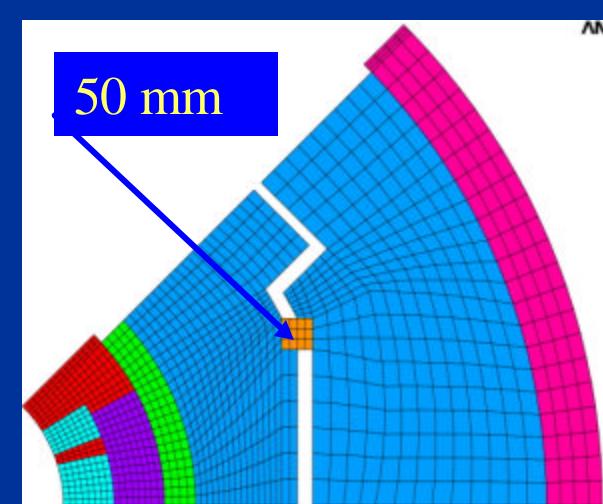
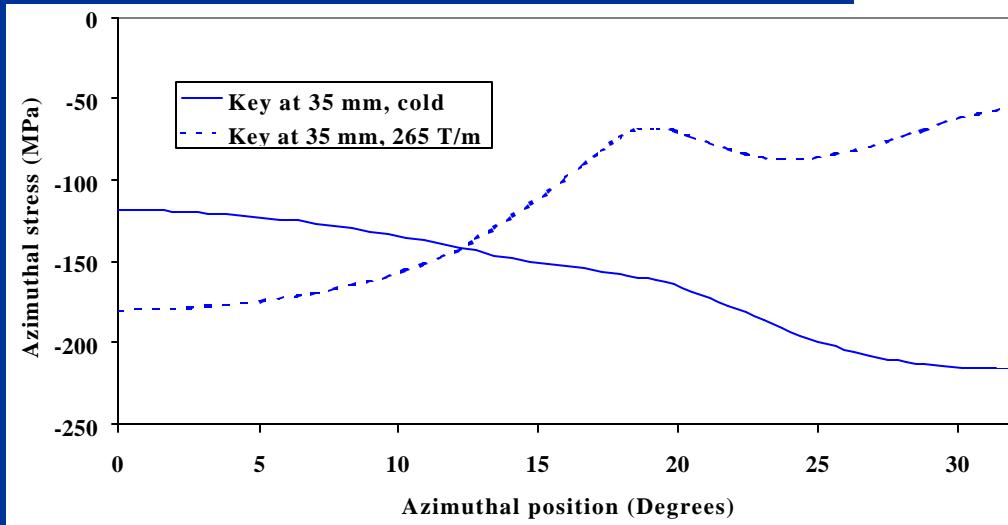
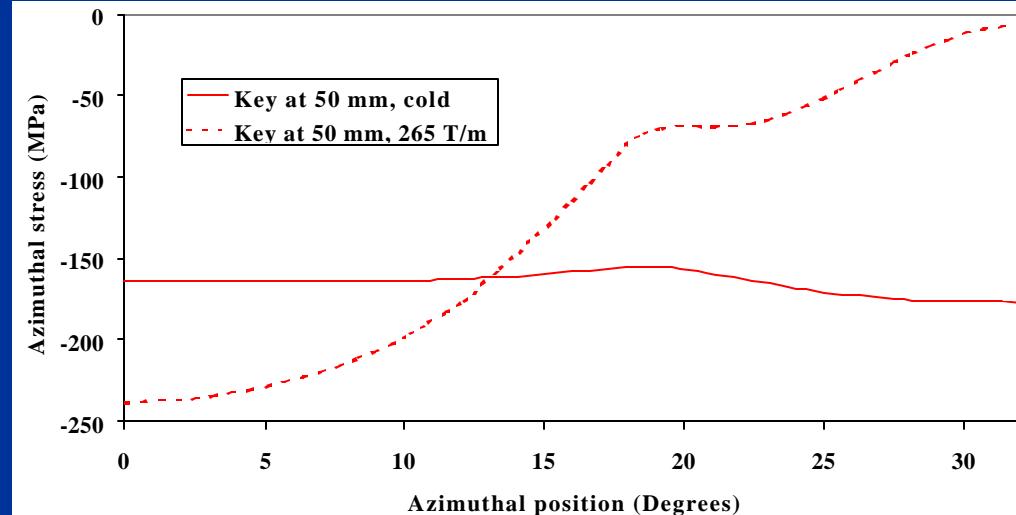
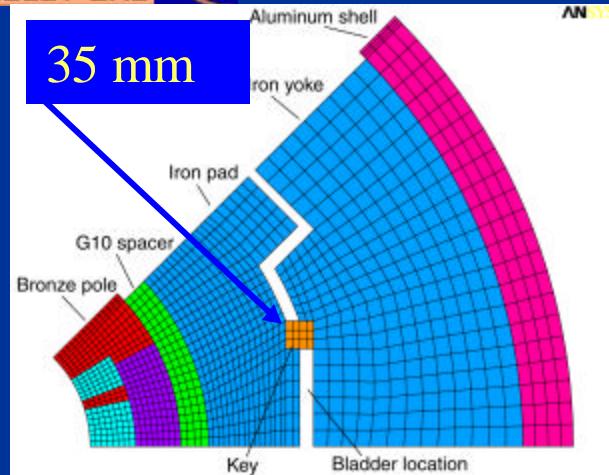
1. Measure strain
(warm/cold)
2. Measure ID
displacements
3. Compare with ANSYS
4. Vary key size

Coil stress can be derived from strain gauges placed on the outer structural shell and axial end rods



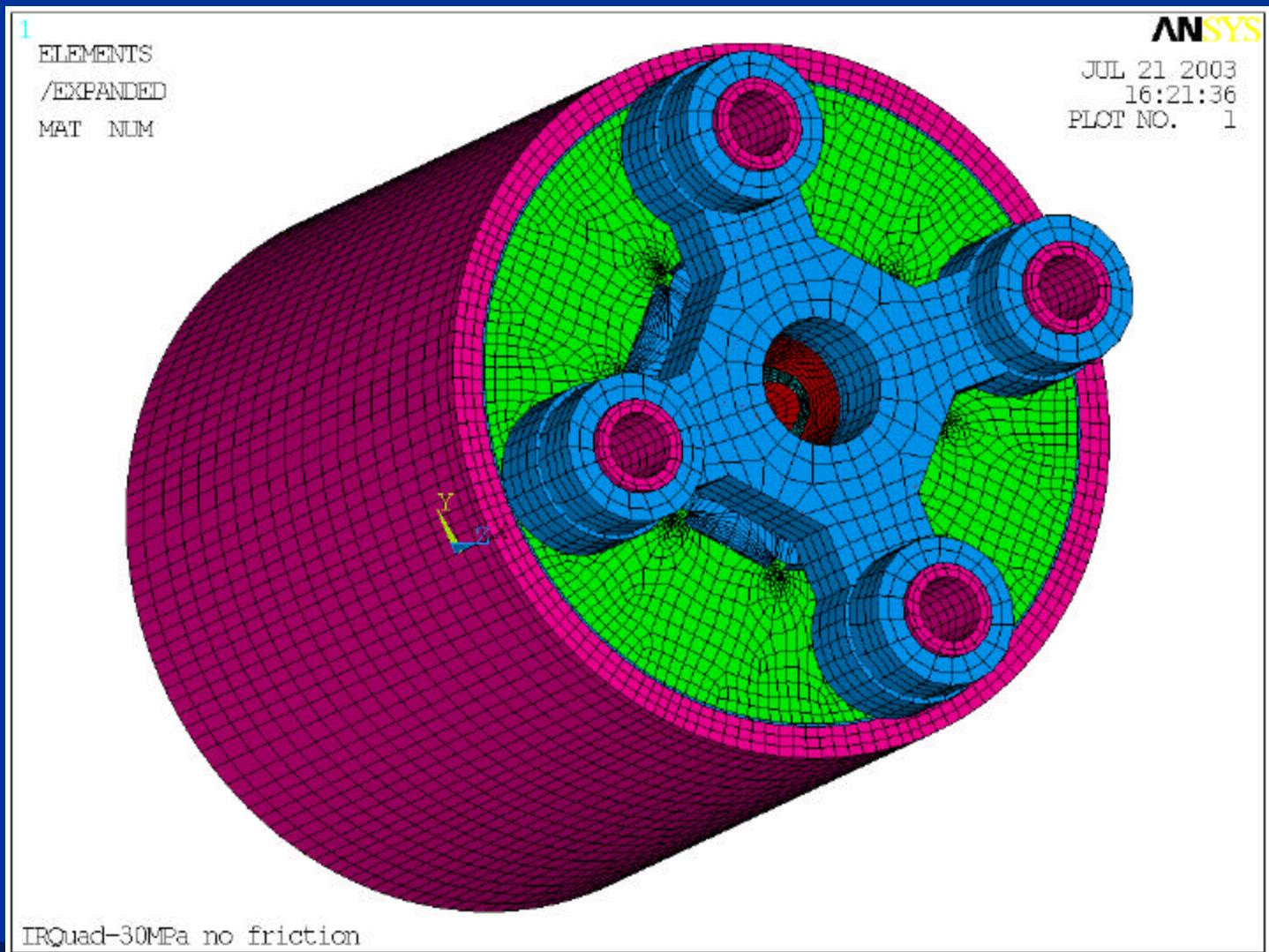
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Coil Stress and key position





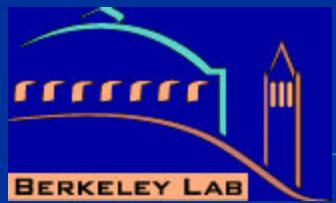
Magnet Assembly - ANSYS



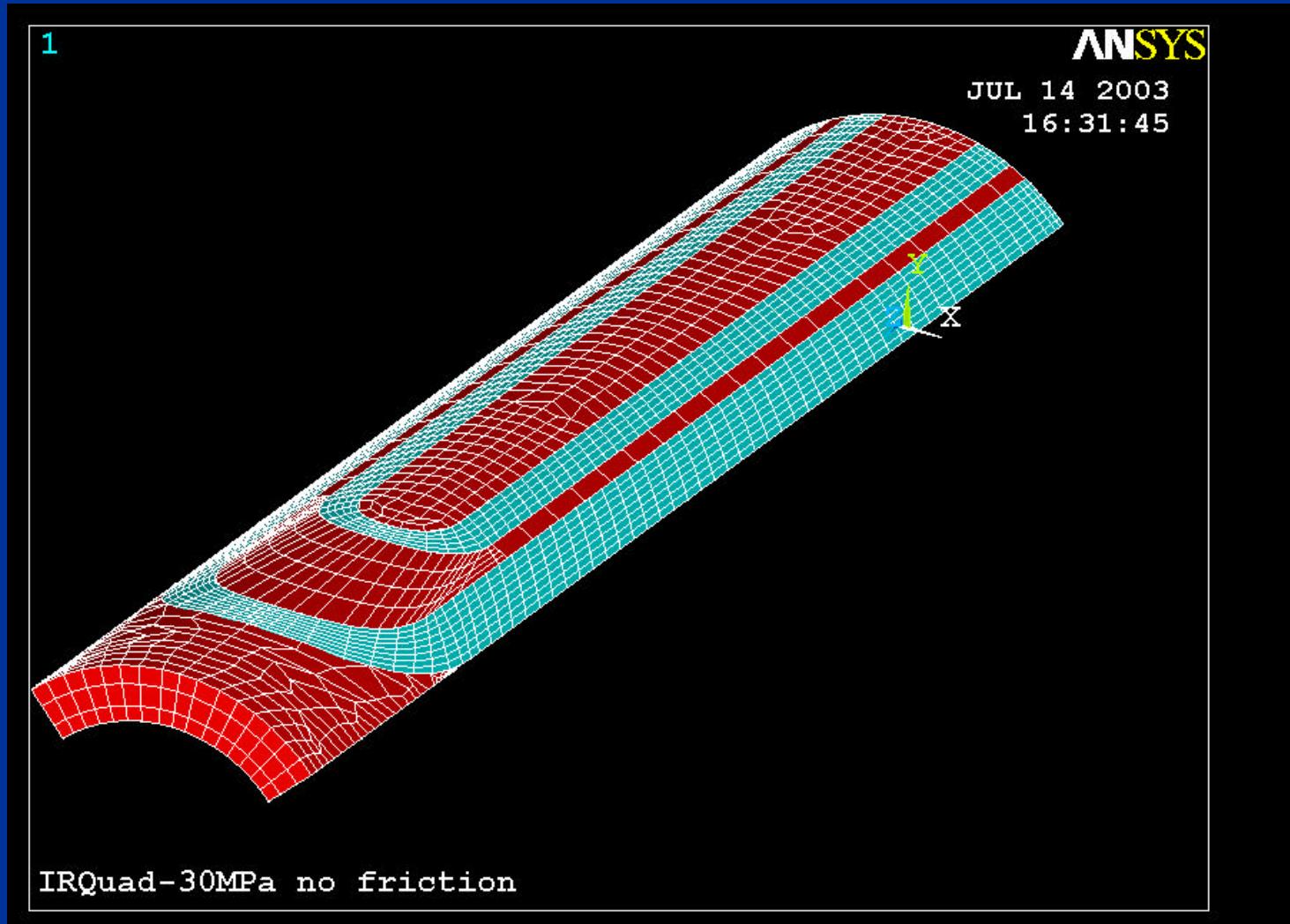
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Layer 1



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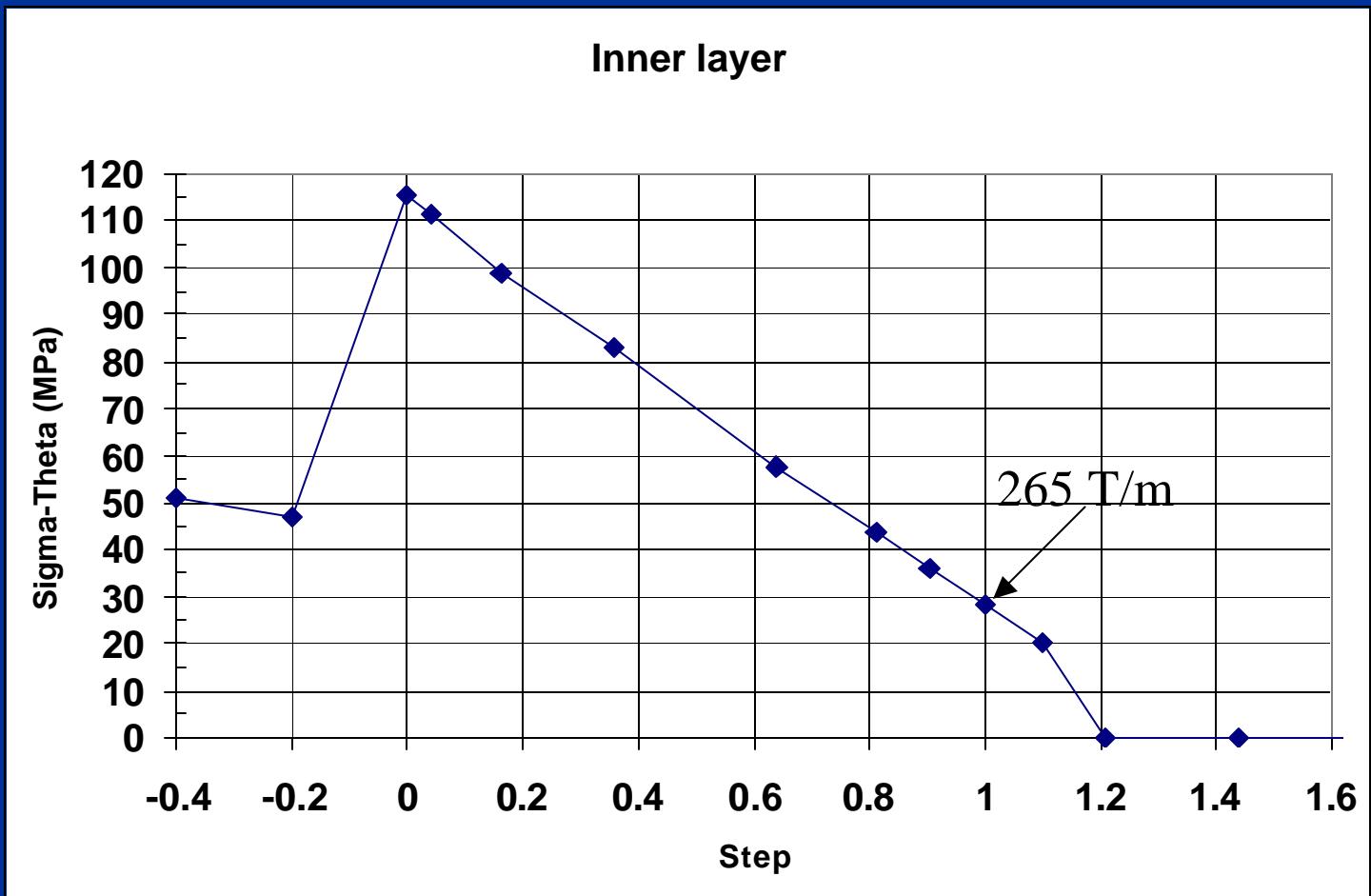
Time-Step

1. **Bladder pressure 30 MPa**
2. **Keys on bladders removed**
3. **Cool-down to 4.2K**
4. $I=14000A \text{ (} 0.7I_{max}, I^2=0.49 \text{)}$
5. $I=16000A \text{ (} 0.8I_{max}, I^2=0.64 \text{)}$
6. $I=18000A \text{ (} 0.9I_{max}, I^2=0.81 \text{)}$
7. $I=19000A \text{ (} 0.95I_{max}, I^2=0.9025 \text{)}$
8. $I=19500A \text{ (} 0.975I_{max}, I^2=0.9506 \text{)}$
9. **$I=20000A \text{ (} 1.0 I_{max}, I^2=1.0 \text{)}$**
10. $I=21000A \text{ (} 1.05I_{max}, I^2=1.1025 \text{)}$
11. $I=22000A \text{ (} 1.1 I_{max}, I^2=1.21 \text{)}$
12. $I=24000A \text{ (} 1.2I_{max}, I^2=1.44 \text{)}$

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Inner layer Stress



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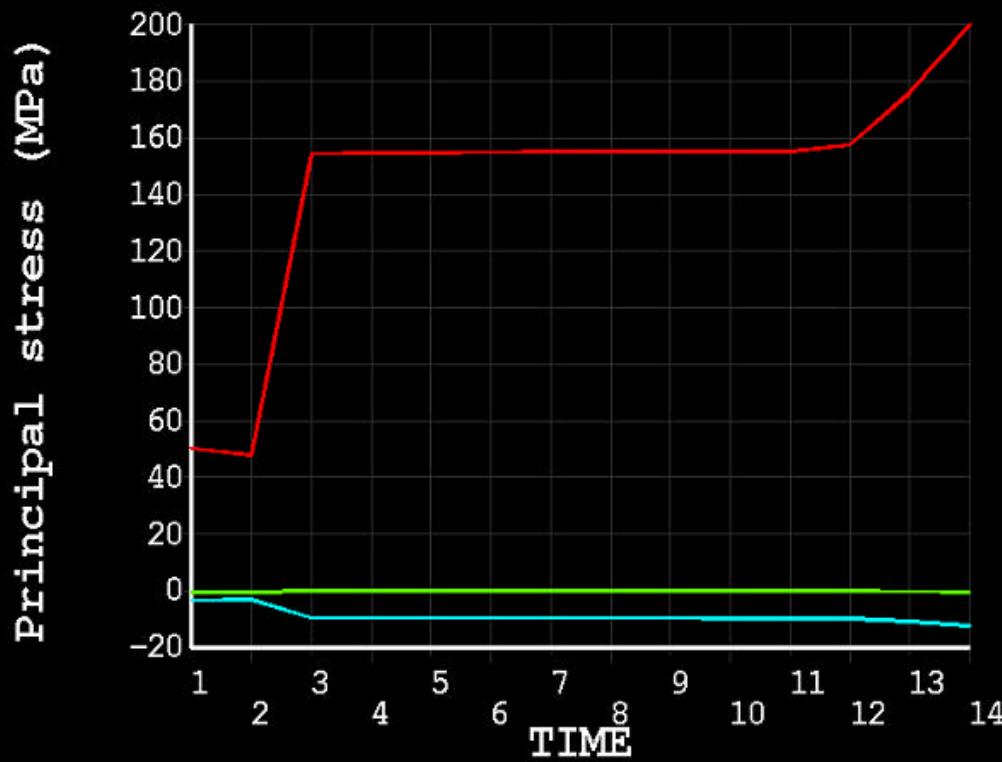


Azimuthal Stress in Shell, mu=0

ANSYS

JUL 17 2003
17:00:04
PLOT NO. 1

S1_2
S2_3
S3_4

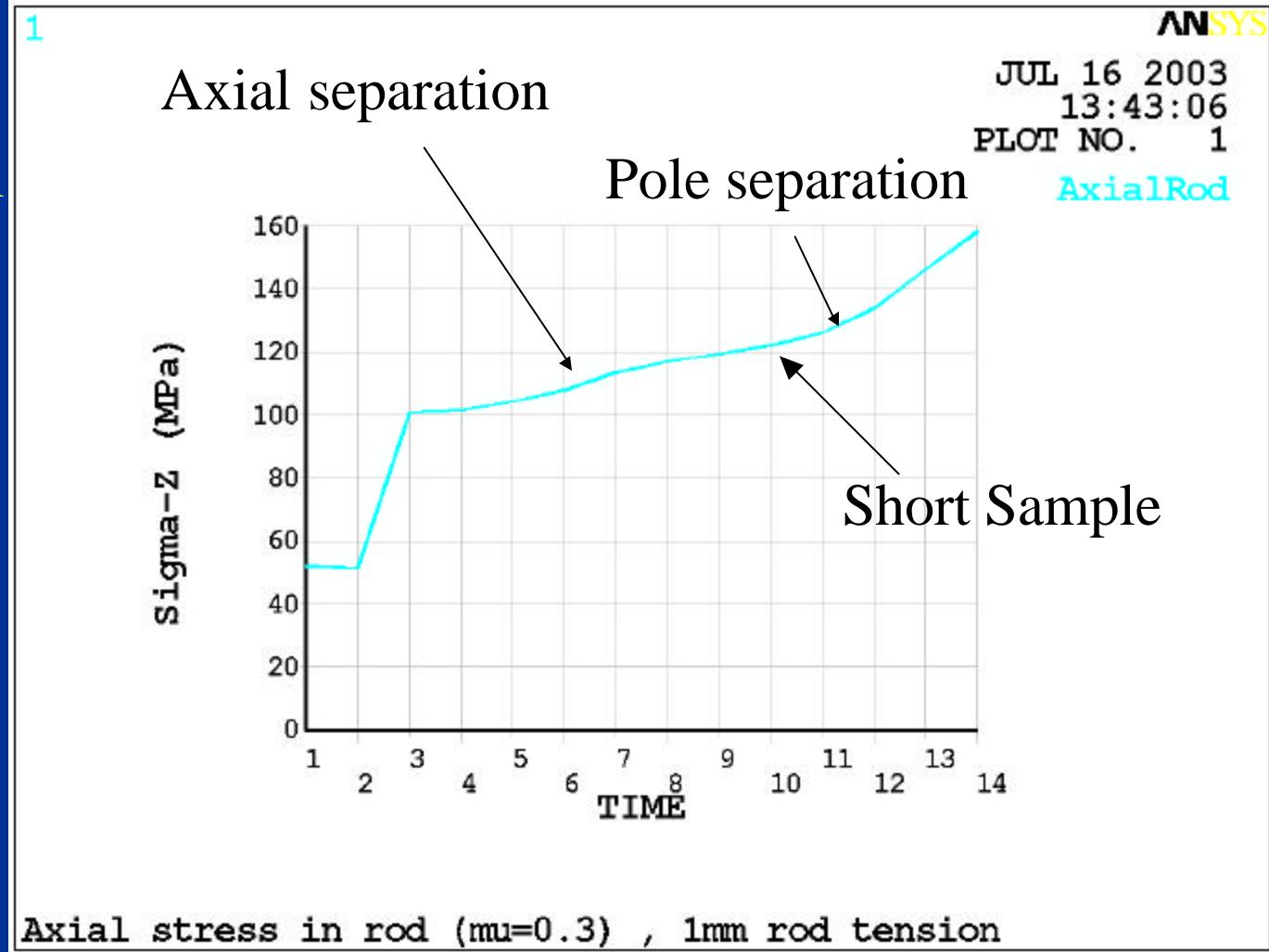


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Axial Stress in Rod

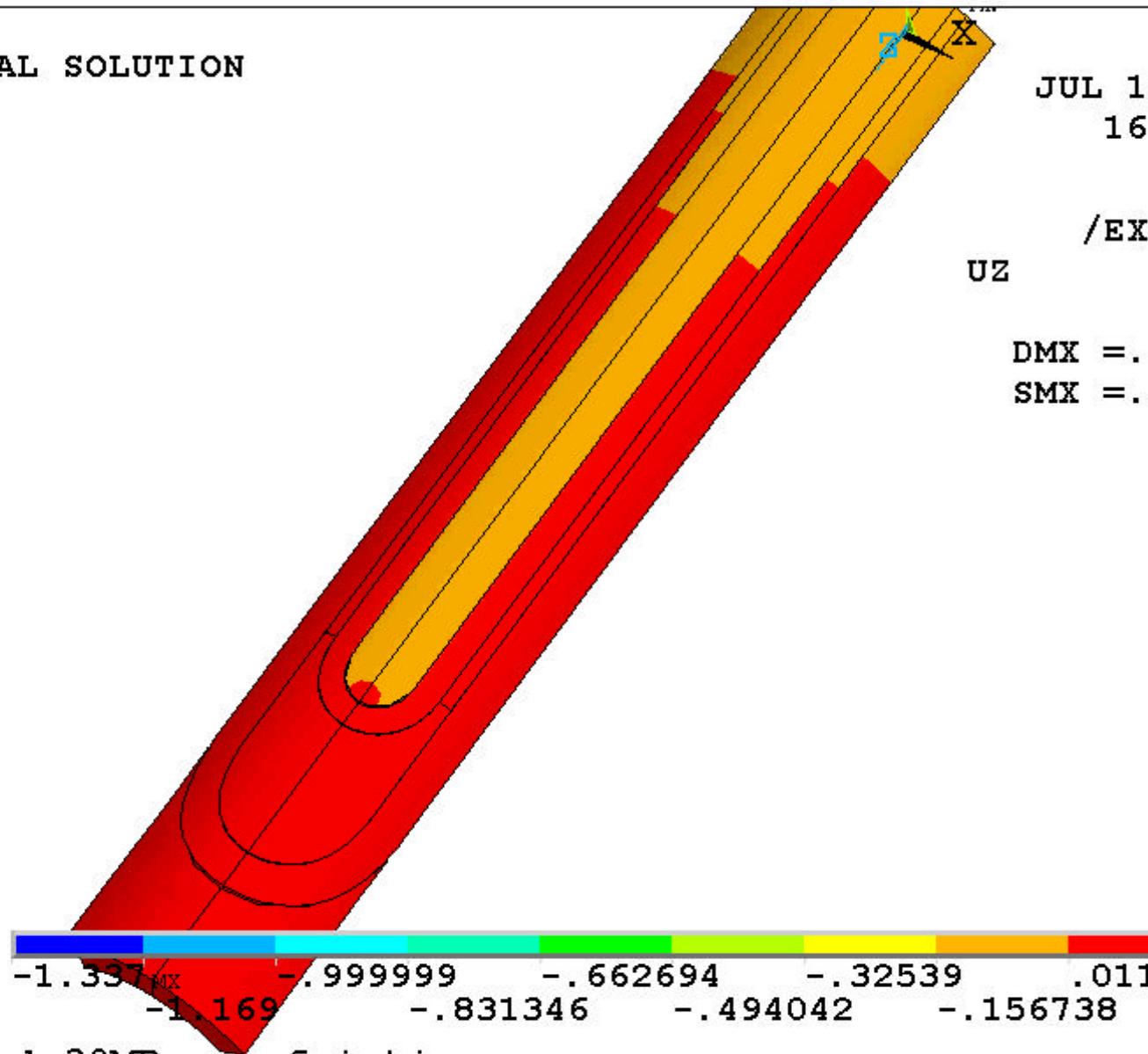
Axial rods pre-tension at 1mm = 55 MPa



1

NODAL SOLUTION

ANSYS

JUL 14 2003
16:39:21TIME=1
/EXPANDED
UZ (AVG)
RSYS=0
DMX = .187207
SMX = .178888

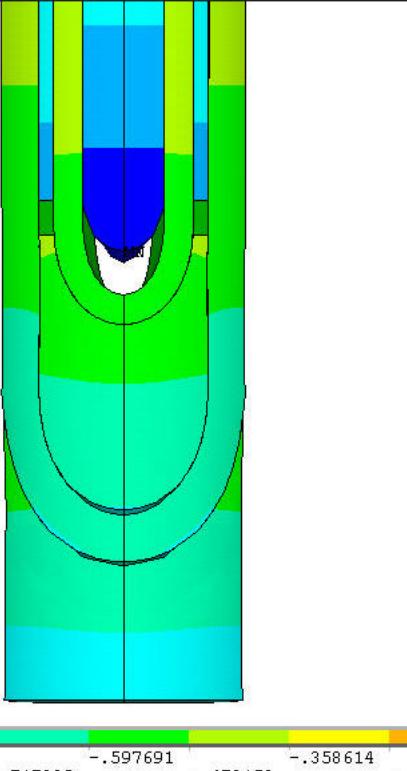
IRQuad-30MPa no friction



Layer 1 - 1.0Imax

0 friction

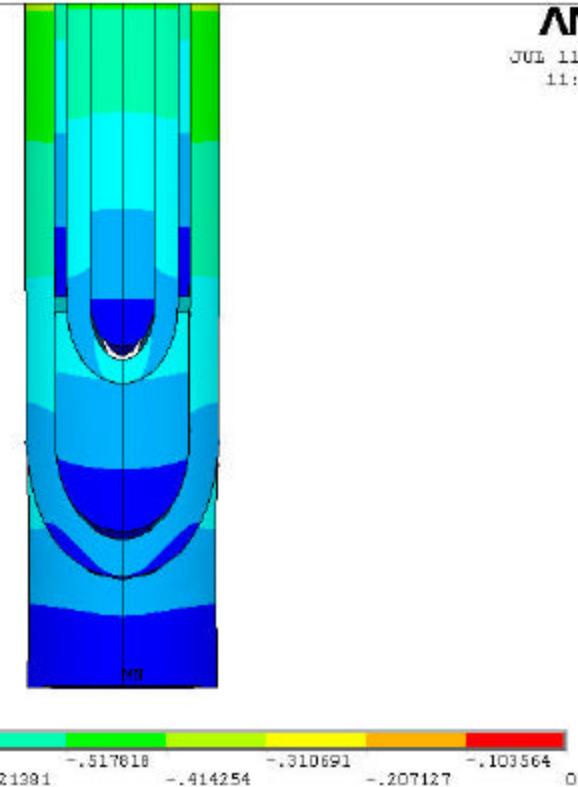
```
1 NODAL SOLUTION  
STEP=9  
SUB =1  
TIME=9  
/EXPANDED  
UZ      (AVG)  
RSYS=0  
DMX =1.106  
SMN =-1.076
```



0.3 friction

```
1 NODAL SOLUTION  
STEP=9  
SUB =1  
TIME=9  
/EXPANDED  
UZ      (AVG)  
RSYS=0  
DMX =.967783  
SMN =-.932072
```

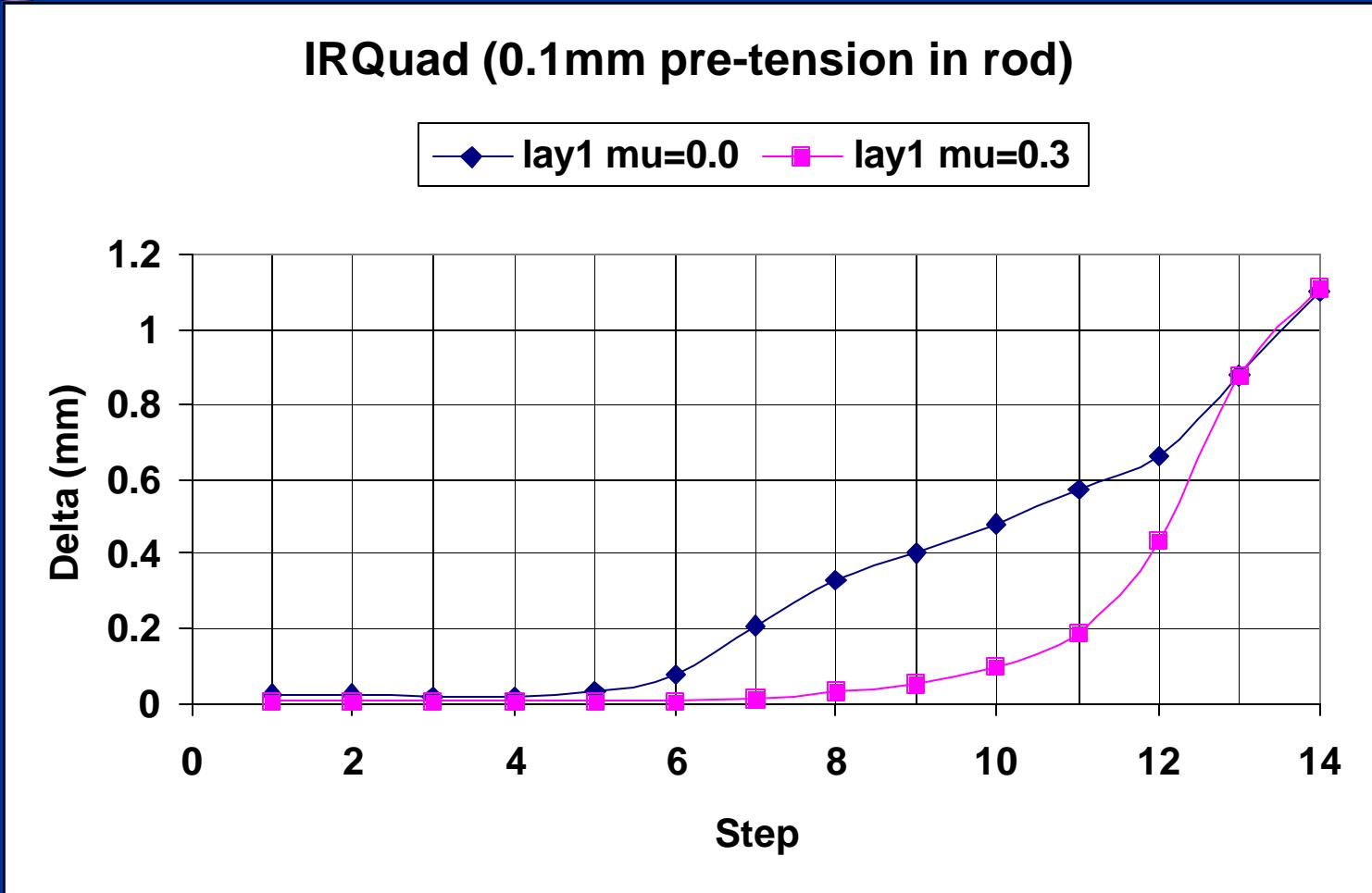
IRQuad-30MPa+0.3 friction



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Training Studies (coil-pole axial slippage – layer 1)



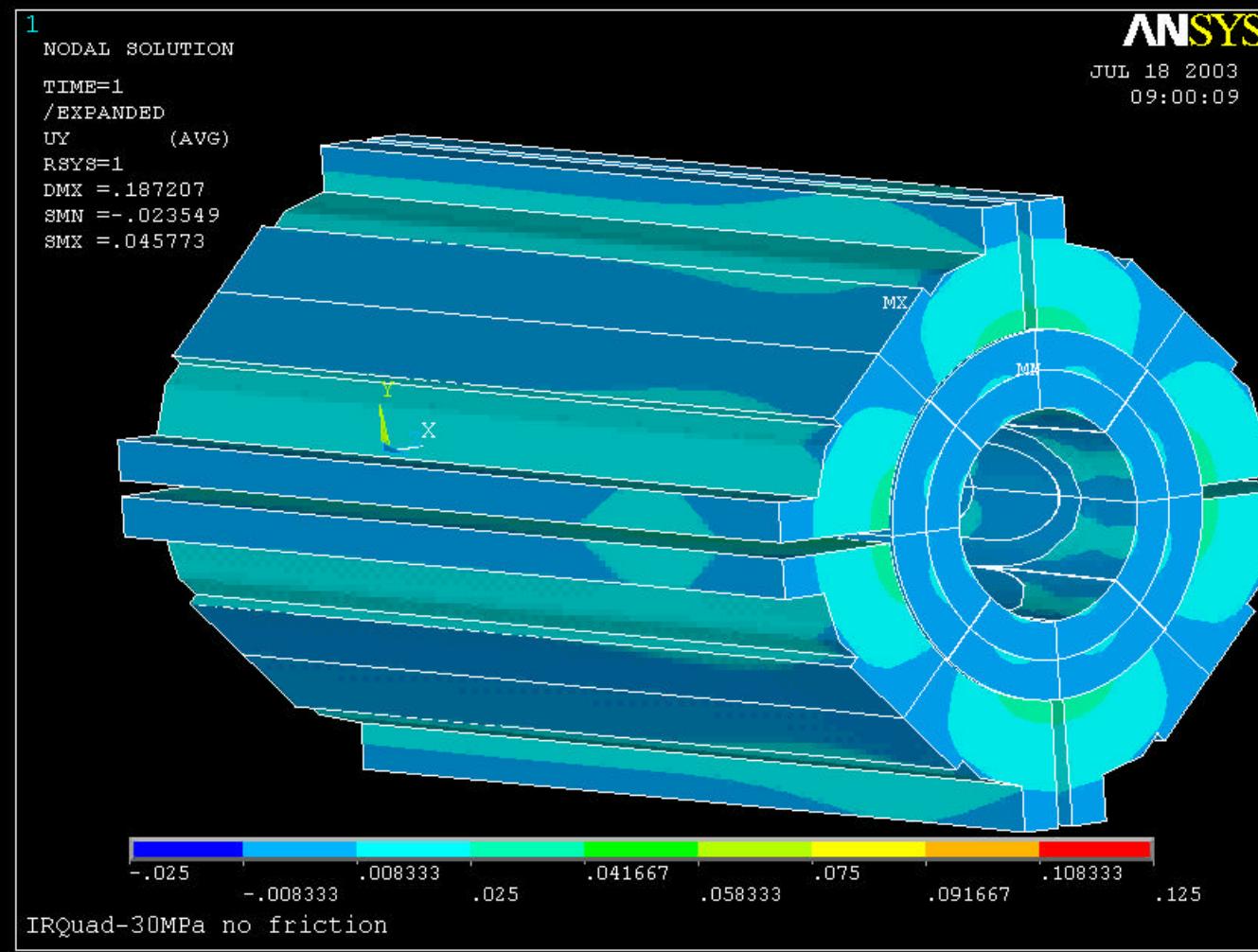
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End Plate and Rods



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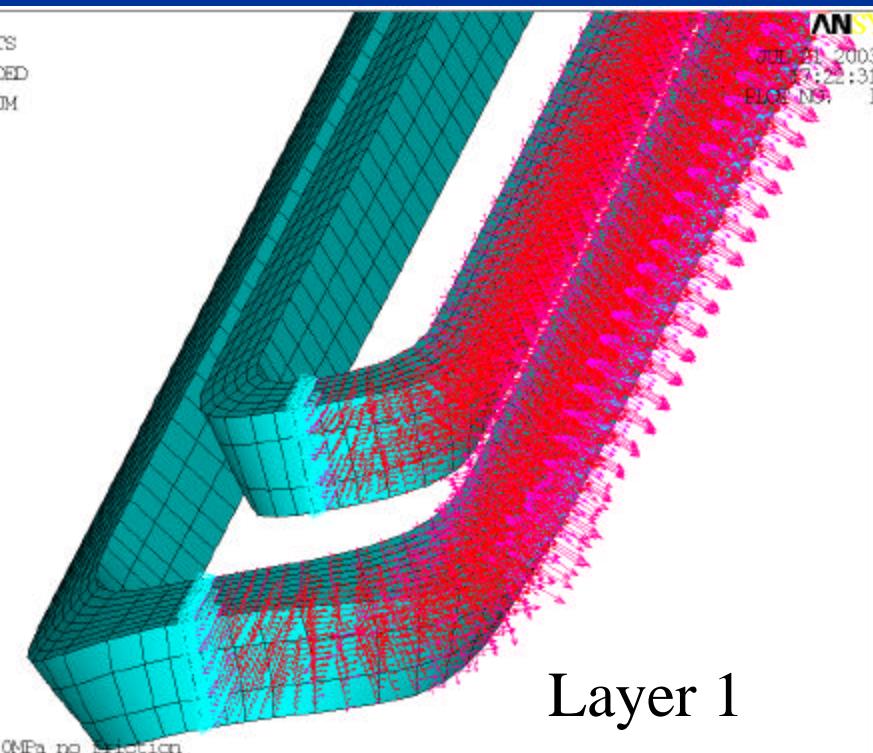
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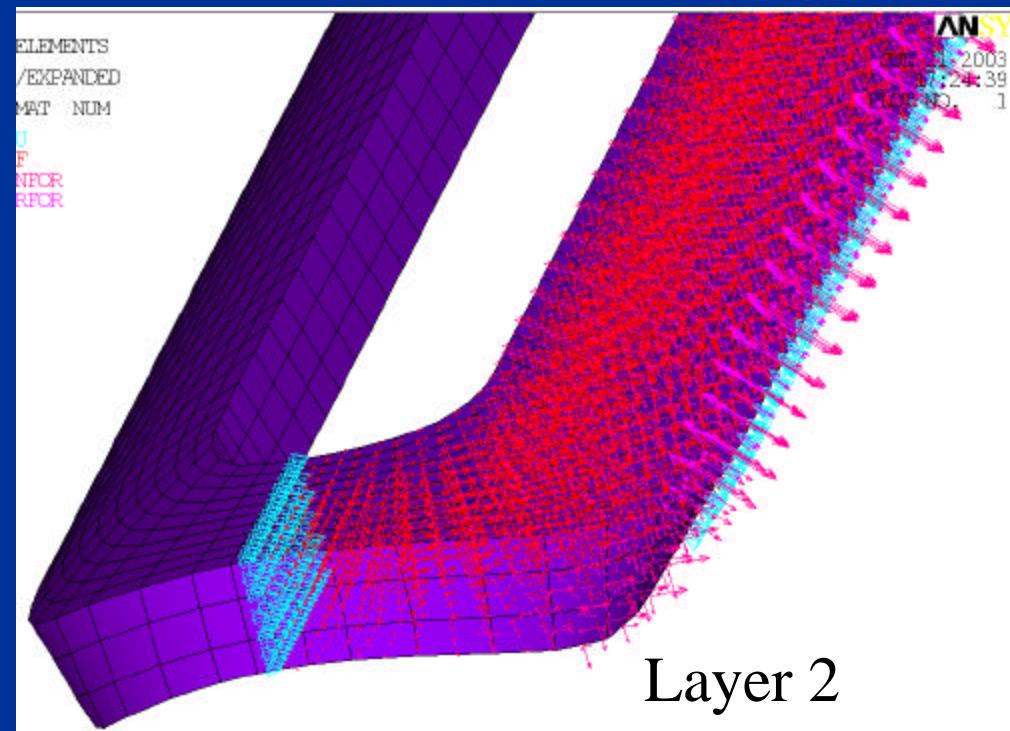


Lorentz Forces



Layer 1

Mapped force/volume from
TOSCA into force/element
in ANSYS

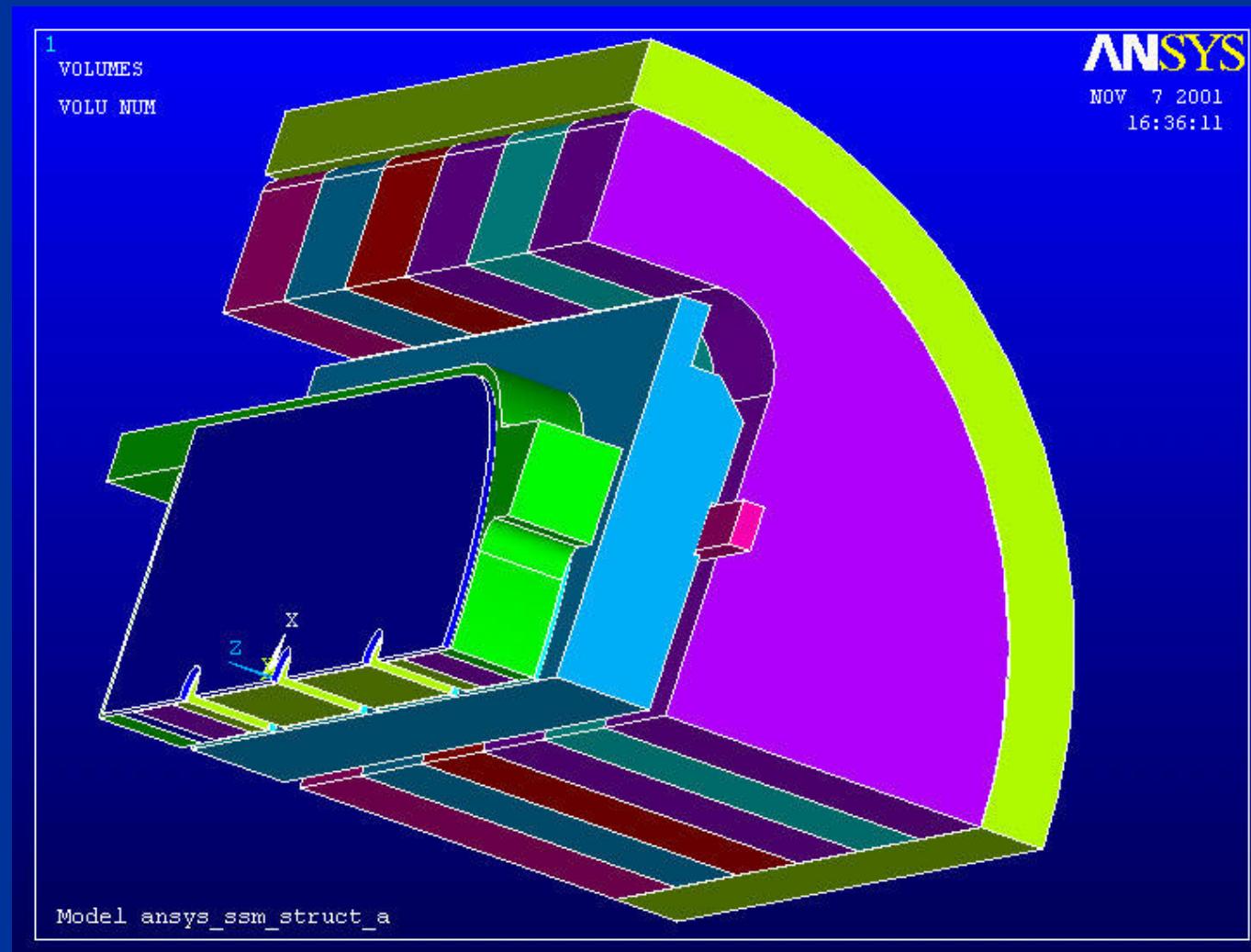


Layer 2

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Subscale magnet



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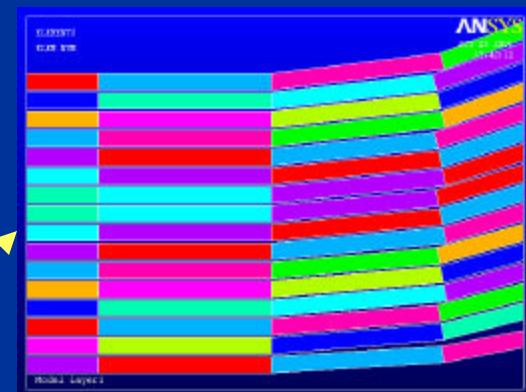
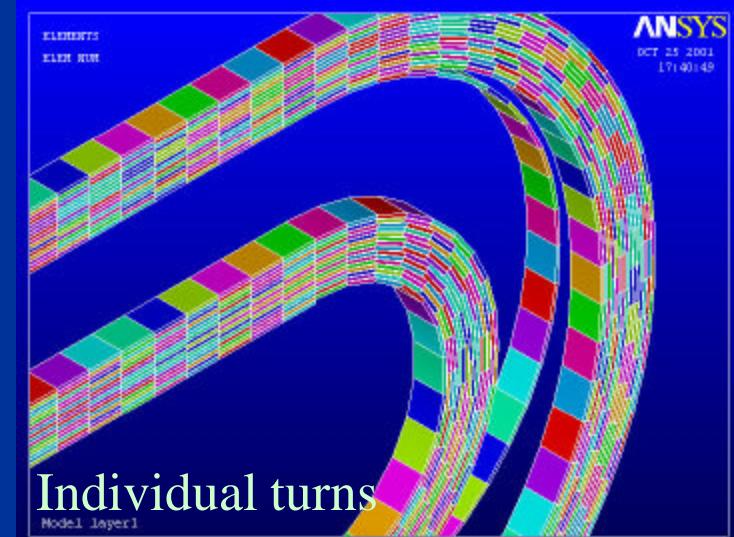
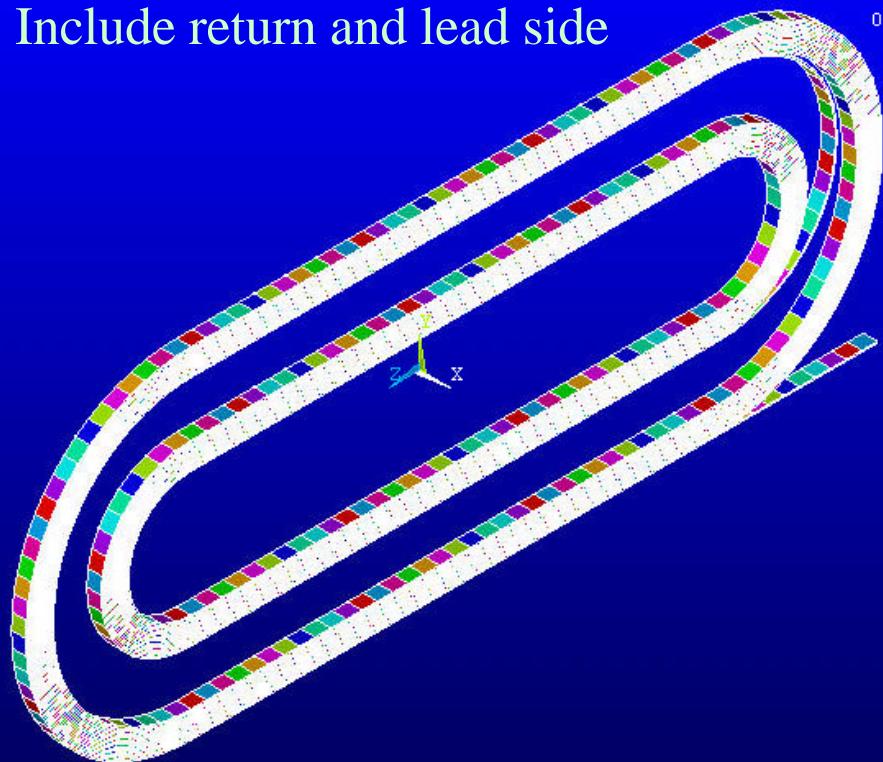
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Coil Modeling (RD3C)

Include return and lead side



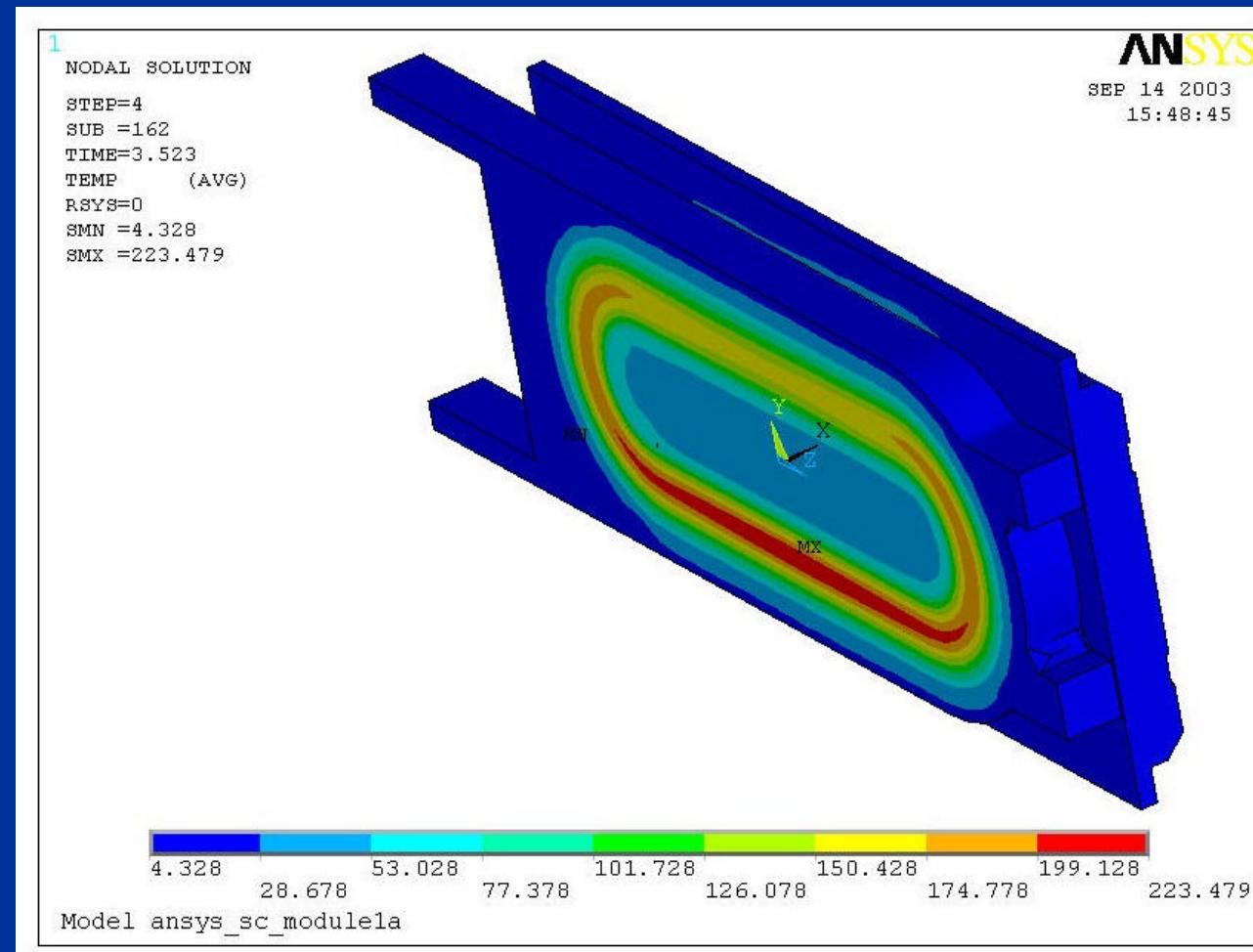
Turn to turn - insulation

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Temperature of Subscale CC

Temperature of skin
after a 3.5 sec
quench propagation



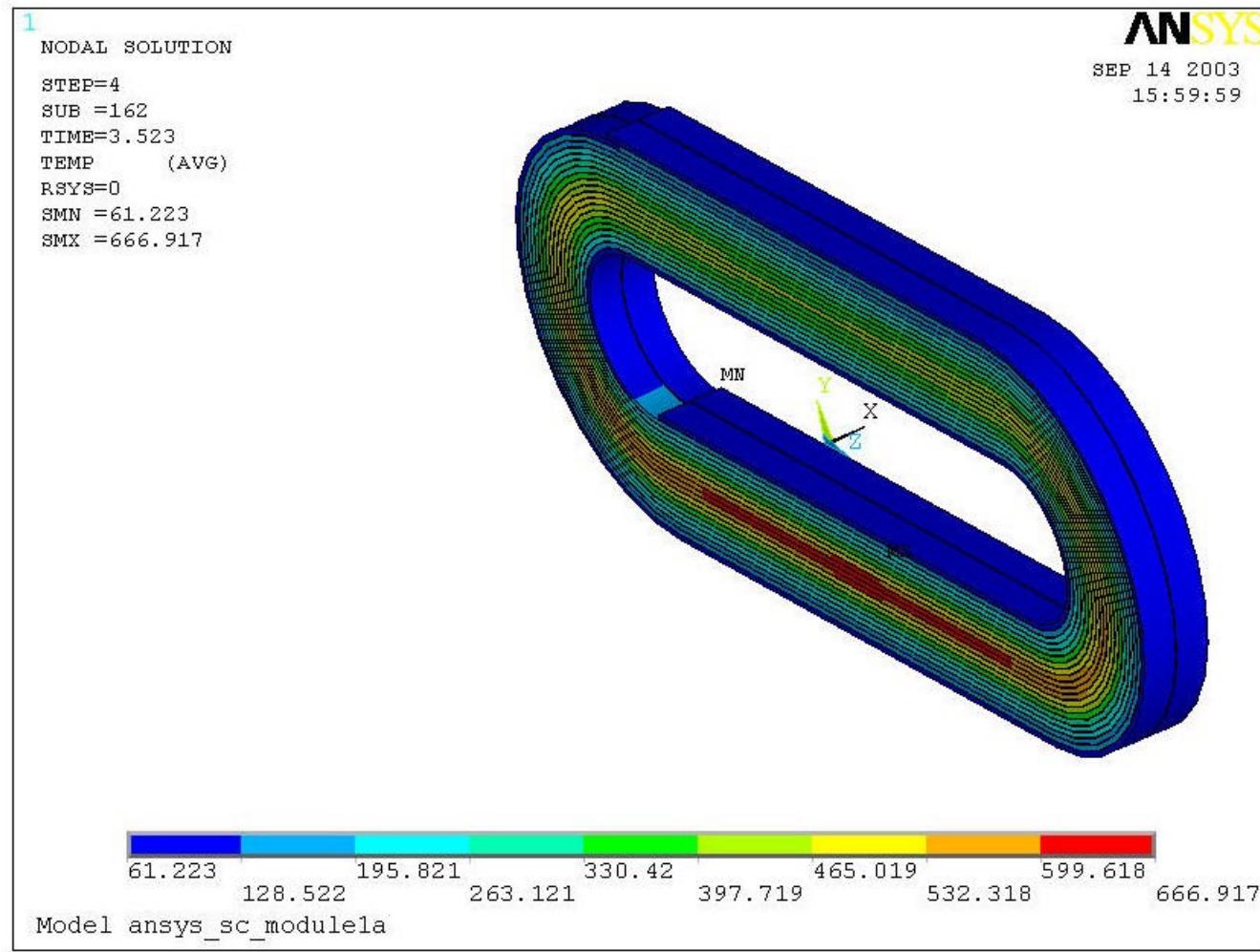
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Temperature of Subscale CC

Temperature of coil
after a 3.5 sec
quench propagation

Voltage and Stress
will be reported at the
MT-18 conference



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Modeling - ANSYS

- A 3D structural analysis of the magnet during assembly, cool-down and operation
- A 3D thermal analysis of the magnet with heat loads
- A 3D thermo-electrical analysis during a quench

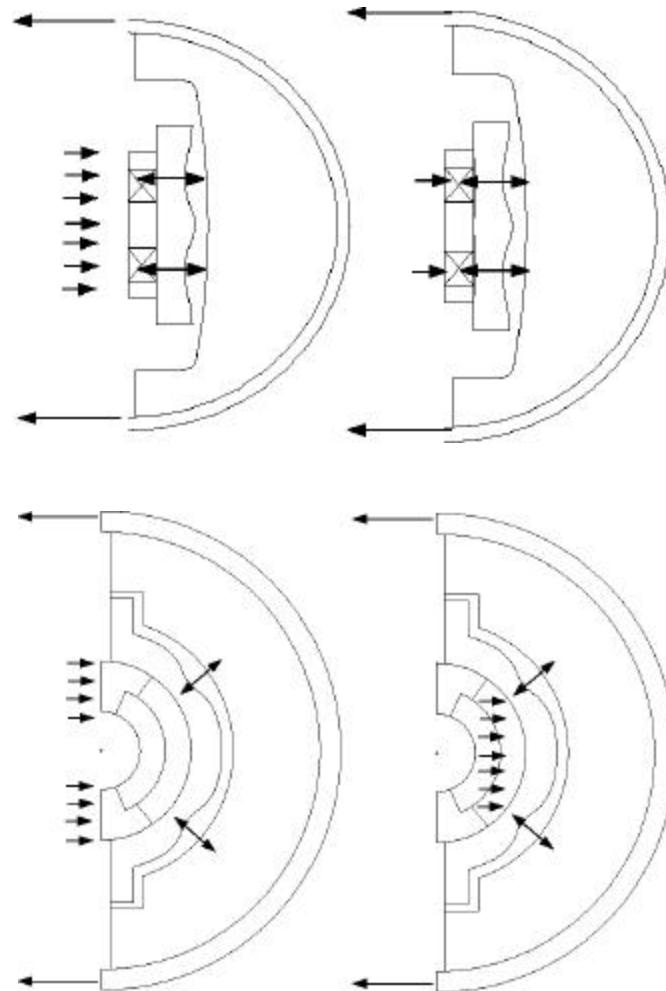
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Shell, Keys, and Bladders – Principal of operation

- ❑ Three main components:
 - ✓ Outer **Shell** - Tension
 - ✓ Intermediate **Yoke and Key** - Transmitters
 - ✓ Inner **Coil** - Compression

- ❑ As Lorentz forces increase, reaction forces decrease leaving the stress in the shell unchanged..



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